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## (54) MANUFACTURING A HARDENED STEEL ARTICLE

(71) We, NORRBOTTENS JÄRN-  
 VERK A.B., a Swedish Body Corporate of  
 S-951 00 Luleå, Sweden, do hereby declare  
 the invention, for which we pray that a patent  
 may be granted to us, and the method by which  
 it is to be performed, to be particularly de-  
 scribed in and by the following statement:—

The invention relates to a method of manu-  
 facturing a hardened steel article, particularly  
 one with small wall thickness and good di-  
 mensional trueness.

For producing hardened and possibly tem-  
 pered thin details, for example of thin sheet  
 metal, preferably below 3 mm. with good  
 dimensional trueness, heretofore the detail after  
 having been formed in a conventional manner  
 was taken out of the forming apparatus, posi-  
 tioned in a holder to prevent subsequent dis-  
 tortion, and thereafter hardened and, possibly,  
 tempered. This procedure is complicated and  
 involves high requirements on the harden-  
 ability of the steel used.

The present invention provides a method  
 of manufacturing a hardened steel article, in  
 which a blank of hardenable steel is heated  
 to hardening temperature and thereafter placed  
 in a forming apparatus in which the blank is  
 formed to the desired final shape by being  
 subjected to substantial deformation and simul-  
 taneous rapid cooling, such that a martensitic  
 and/or bainitic structure is obtained while  
 the blank remains in the forming apparatus,  
 which serves as a gauge for preventing distor-  
 tion of the blank.

Preferably a blank of uniform thickness is  
 used, and preferably the thickness of the  
 formed article at any point differs from the  
 thickness of the blank by no more than 25%  
 of the thickness of the blank.

The steel utilized as starting material is pre-

ferably a boron-alloyed carbon steel or carbon  
 manganese steel. In order to obtain the desired  
 combination of hardness and toughness which  
 may render the tempering step unnecessary,  
 a steel may be used which contains, by weight,  
 less than 0.4% carbon, silicon in an amount  
 depending on the steel production method but  
 in general being insignificant, 0.5 to 2.0% man-  
 ganese, at maximum 0.05% phosphorus and  
 at maximum 0.05 sulphur, 0.1 to 0.5% chrom-  
 ium and/or 0.05 to 0.5% molybdenum, up to  
 0.1% titanium, 0.0005 to 0.01% boron, up to  
 a total of 0.1% aluminium and possibly in-  
 significant low contents of copper and nickel,  
 possibly in contents of up to 0.2% each.

Preferably the steel contains less than or  
 equal to 0.25% (preferably 0.15 to 0.25%)  
 carbon, silicon in an amount depending on the  
 steel production method but in general being  
 insignificant, 0.5 to 1.5% (preferably 0.7 to  
 1.5%) manganese, at maximum 0.03% phos-  
 phorus and at maximum 0.04% sulphur, 0.1 to  
 0.3% chromium and/or 0.05 to 0.5% molyb-  
 denum, 0.02 to 0.1% (preferably 0.02 to  
 0.05%) titanium, 0.0005 to 0.007% (prefer-  
 ably 0.0005 to 0.005%) boron, 0.03 to 0.1%  
 (preferably 0.03 to 0.07%) aluminium, and  
 possibly low insignificant contents of copper  
 and nickel, possibly in contents of up to 0.2%  
 each.

The steel is heated to hardening tempera-  
 ture, i.e. to a temperature above  $A_c$ , where the  
 steel will be in austenitic state. The steel pre-  
 ferably is heated to a temperature between  
 775° C. and 1000° C.

The forming operation is preferably a press-  
 ing operation, but the method can also use  
 other forming techniques, such as drop forg-  
 ing, extrusion and explosive forming.

In the preferred pressing operation the blank

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is formed between two tools or against one tool by means of some pressure medium. It is desirable to apply a quick-operating press so designed that the position and speed of the tool(s) can be controlled during the entire process. It is, thus, desired that forming takes place in less than five seconds, preferably less than three seconds, so that forming is completed before the desired hardening structure is attained.

The forming and cooling operation is ideally to be carried out so rapidly that a fine-grain martensitic and/or bainitic structure is obtained. The necessary rapidity depends on the analysis of the steel, i.e. on its Continuous Cooling Transformation graph (CCT-graph). The rapid cooling preferably continues after deformation has been completed, with the pressed blank remaining in the forming device. Cooling of the pressed article may be effected indirectly by cooling parts of the forming device and/or directly by bringing the pressed blank into direct contact with some cooling medium. The tool or tools serves or serve as a gauge during the cooling operation, so that the final product obtained has good dimensional trueness.

By using the preferred steel it is possible to manufacture thin bearing sheet or shell structures with high strength. The combination of high strength and good tenacity permits the manufacture also of energy absorbing (i.e. shock absorbing) details. Hardened (untempered) sheet structures are intended especially for use in transport vehicles for parts which can be expected to have to take up shocks during collisions, primarily the bumpers, but also other body details. It may generally be said that vehicle parts which are exposed or for which there is a risk of becoming exposed to heavy shocks advantageously should be manufactured according to the invention by utilizing the preferred steel specified above.

It is a great advantage that the steel can be used in hardened state without subsequent tempering, because it reduces the heat treatment by one step and eliminates a source of dimensional inaccuracy. The resulting articles, moreover, are harder.

For achieving a full effect of the low boron content of 0.0005 to 0.01% the boron addition to the steel is to be made after the contents of titanium and aluminum indicated above have been added, so that oxygen and nitrogen are already bound when boron is being added. Boron steel is a weldable structural steel, which is given extremely high strength in combination with good toughness by a simple heat treatment. A yield point of greater than 120 kp/mm<sup>2</sup>, with an elongation of about 10% at fracture, is not unusual. The relatively high hardness in combination with a good elongation after hardening provides the boron steel with very good shock-absorbing properties. With respect to its base analysis, the boron steel is a carbon manganese steel, which by a special metallurgical treatment and by alloying with boron has been given very good hardening properties. Owing to the boron addition, the steel after its hardening by water or oil quenching exhibits a fine-grain structure consisting of low-temperature bainite and tempered high-temperature martensite. It is by this structure that the boron steel shows its combination of hardness and toughness, in contrast to a steel not alloyed with boron, which after hardening exhibits a brittle hardening structure.

A boron-alloyed steel has, in addition to the aforesaid improvements in its mechanical properties, a much better penetration hardening capacity than a steel with the same base analysis without a boron addition.

The very high strength properties and the good shock-absorbing properties are obtained after the hardening. A suitable hardening temperature, between 775° C. and 1000° C., is 900° C. For wall thicknesses below 6 mm quenching in oil or salt water is recommended.

#### EXAMPLE.

Table 1 shows the results by way of strength values and hardnesses for six different steel analyses formed into hardened articles according to the invention having various wall thicknesses. The following values may conclusively be stated as guide values for the mechanical properties:

Hot rolled or cold rolled and annealed state:

$\delta_S$ kp/mm <sup>2</sup>	$\delta_B$ kp/mm <sup>2</sup>	$\delta_5$ %
36-42	50-60	23-55

( $\delta_S$  = yield stress,  $\delta_B$  = ultimate tensile strength,  $\delta_5$  = elongation at fracture).

- 5 Hardened state: The following guide values are obtained, depending somewhat on dimension and hardening medium:

$\delta_S$ kp/mm <sup>2</sup>	$\delta_B$ kp/mm <sup>2</sup>	$\delta_5$ %	Hardness HRC	Toughness KCU 0°C kp/cm <sup>2</sup>
120-150	150-170	8-12	45-50	5-10

- 10 (HRC = Rockwell 'C' hardness)  
(KCU = impact energy, tested in accordance with ISO/R83).

- 15 With respect to their weldability, the boron-alloyed steels are to be judged after their base analysis, thus their carbon and manganese contents, because the structure attained in the heat-affected zone is not sensitive to hydrogen embrittlement. The boron steels listed in the

Table, therefore, can easily be welded as normal high-strength structural steels.

When the boron steel is to be welded prior to the forming and hardening, the properties of the base material after hardening can be attained also in the welding joint by using special electrodes adapted to the boron steels.

TABLE I

Examples of strength achieved after hardening

Charge	Thick- ness mm	Analysis									Strength		Hardness	Hardening medium	
		C %	Si %	Mn %	P %	S %	Cr %	Ti %	B %	Al %	0.2 B Kp/mm <sup>2</sup>	5 %			
B 6959	6	0.24	0.37	0.94	0.030	0.019	0.197	0.040	0.0050	0.060	118 132	174 179	10 11	HB 470	10% saline solution
B 7000	6	0.23	0.31	0.95	0.022	0.018	0.154	0.036	0.0031	0.123	120	164	10	HV10 486	"
B 7000	4	"	"	"	"	"	"	"	"	"	145	167	—	HB 455	
B 8307	6	0.19	0.31	0.77	0.016	0.016	0.207	0.032	0.0029	0.046	112 114	155 156	11 11	"	"
A 2197	4	0.19	0.23	0.77	0.024	0.024	0.195	0.030	0.0031	0.040	119 119	153 158	10 12		
B 6938	4	0.23	0.39	0.87	0.020	0.023	0.196	0.043	0.0034	0.069	102 96	143 134	8 8	HRC 42	Oil
B 8307	6	0.19	0.31	0.77	0.016	0.016	0.207	0.032	0.0029	0.046	85 88	96 110	9 9	"	"
B 8500	1.75	0.24	0.27	0.70	0.016	0.019	0.18	0.040	0.0050	0.139	123	165	10	HV5 550	10% saline solution
	92										136	9	HV5 435	Oil	
													HV 400-450	Tool	
													HV 420-490	Tool	

## WHAT WE CLAIM IS:—

1. A method of manufacturing a hardened steel article, in which a blank of hardenable steel is heated to hardening temperature and thereafter placed in a forming apparatus in which the blank is formed to the desired final shape by being subjected to substantial deformation and simultaneous rapid cooling, such that a martensitic and/or bainitic structure is obtained while the blank remains in the forming apparatus, which serves as a gauge for preventing distortion of the blank.
2. A method as claimed in claim 1, in which the blank is heated to a temperature above  $AC_1$ .
3. A method as claimed in claim 2, in which the said temperature is between  $775^\circ\text{C}$ . and  $1000^\circ\text{C}$ .
4. A method as claimed in any of claims 1 to 3, in which deformation and cooling are carried out so rapidly that a fine-grain martensitic and/or bainitic structure is obtained.
5. A method as claimed in any of the preceding claims, in which forming is carried out between two tools, which are pressed together rapidly.
6. A method as claimed in any of claims 1 to 4, in which forming is carried out against one tool by means of a pressure medium.
7. A method as claimed in any of the preceding claims, in which the rapid cooling continues after deformation has been completed, the blank remaining in the forming apparatus.
8. A method as claimed in any of the preceding claims, in which cooling is effected by cooling parts of the forming apparatus.
9. A method as claimed in any of the preceding claims, in which cooling is effected by

contacting the blank directly with a coolant.

10. A method as claimed in any of the preceding claims, in which the blank is of uniform thickness.

11. A method as claimed in claim 10, in which the thickness of the formed article at any point differs from the thickness of the blank by at most 25% of the thickness of the blank.

12. A method as claimed in any of the preceding claims, in which the hardenable steel contains, by weight, less than 0.4% carbon, 0.5 to 2.0% manganese, at maximum 0.05% phosphorus and at maximum 0.05% sulphur, 0.1 to 0.5% chromium and/or 0.05 to 0.5% molybdenum, up to 0.1% titanium, 0.0005 to 0.1% boron, and up to 0.1% aluminium, the balance being iron and impurities including silicon.

13. A method as claimed in claim 12, in which the steel contains, by weight less than or equal to 0.25% (preferably 0.15 to 0.25%) carbon, 0.5 to 1.5% (preferably 0.7 to 1.5%) manganese, at maximum 0.03% phosphorus and at maximum 0.04% sulphur, 0.1 to 0.3% chromium and/or 0.05 to 0.5% molybdenum, 0.02 to 0.1% (preferably 0.02 to 0.05%) titanium, 0.0005 to 0.007% (preferably 0.0005 to 0.005%) boron, and 0.03 to 0.1% (preferably 0.03 to 0.07%) aluminium.

14. A method of manufacturing a hardened steel article substantially as described herein with reference to the Example.

15. A hardened steel article manufactured by a method according to any of the preceding claims.

MARKS & CLERK.